MODIS/Snow Project
Quarterly Report (January - March 1994)
Submitted by D.K. Hall/974

Summary

During the last 3 months, considerable progress has been made on improving the snow-mapping algorithm and determination of errors involved in snow mapping using thematic mapper data. For example, errors were calculated for snow mapping in mountainous areas using TM data, due to topographic effects. The Algorithm Theoretical Basis Document has been revised and submitted for peer review and 3 abstracts have been submitted to conferences; 4 papers are in preparation. Field work and concurrent overflights have been conducted in conjunction with the BOREAS project and 2 MODIS/snow-related talks have been given. Research into the relationship between NDVI and forest density for snow mapping has been conducted, as has research into classification of global snow cover, and the energy balance of patchy snow cover.

Error analysis of SNOMAP (D. Hall, G. Riggs/RDC). SNOMAP is the algorithm that is under development to map snow using thematic mapper (TM) and MODIS data. Analysis of the results of the SNOMAP algorithm applied to a TM scene covering Glacier National Park, Montana reveals that the use of reflectances calculated from the TM digital numbers (DNs) increases the measured snow-covered area by about 10 percent. Field work done at the time of acquisition of the 14 March 1991 TM scene reveals that the amount of snow mapped using the reflectances versus the DNs is more realistic.

The normalized difference vegetation index (NDVI) was calculated for the 14 March 1991 TM scene covering Glacier National Park. The results show that the areas having the highest NDVIs are areas where less snow is mapped by SNOMAP. These are areas known to be snow covered as determined from field work. The high tree canopy density obliterates the snow below. There is potentially >10 percent more snow cover (under the trees) in this scene than is mapped using SNOMAP.

Significant errors in mapping snow are inherent in mountainous areas if satellite data are used alone (i.e. without topographic data). A study of the snow conditions in Glacier National Park shows that when digital elevation model (DEM) data are applied to the area, and when snow is mapped using SNOMAP, the accuracy of the resulting snow map is increased. Without topographic information, the TM data, used alone, are quite good at mapping snow in non-forested areas that are relatively flat. In areas of high relief, however, the actual amount of snow may be 5 times (or more) greater than that mapped using TM data alone. This was

determined from analysis of TM/DEM registered data. A simple model was developed to describe the relationship between ruggedness of terrain and accuracy of SNOMAP results. A correction factor can be applied to areas of rugged terrain to improve the measurements of snow cover using TM data alone. The results of this work will be presented by D. Hall at the Third Circumpolar Conference on Remote Sensing of Arctic Environments to be held in Fairbanks, Alaska, 16-20 May 1994; a paper is also being prepared.

During the week of February 6, 1994, the winter part of the BOREAS experiment was held in Saskatchewan. D. Hall, A. Chang, J. Foster of Code 974 and G. Liston/USRA went to the site to do snow measurements in support of the BOREAS/MODIS snow projects. Passive microwave sensors were flown on a Canadian Twin Otter, and there was an ER-2 overflight with the MODIS Airborne Simulator (MAS). The snow conditions were good and temperatures were very cold (down to -40^{o} C). Passive microwave data are currently being processed. MAS data have been processed and at least 10 of the 22 flight lines are good. (Most of the flight lines that are not considered good were from the transit flights and not of interest to this project.)

NDVI and forest density (J. Foster/974). In July in Eurasia, high NDVI values cover a much larger area than they do for North America. However, much more of the snow mass in the boreal forest of Eurasia is accounted for using microwave radiometry than is the case in the North American boreal forest. This is the converse of what is expected if NDVI were strictly a measure of vegetation density. Because of the above concerns, the NDVI for the month of October was also examined to see if this month's NDVI values were more closely related to forest density. October is used as a surrogate for winter NDVI since at this time of year, and for boreal forest latitudes, deciduous plants have shed their leaves and chlorophyll production has virtually stopped.

In October as in July, the overall NDVI values are higher in the boreal forest of Eurasia than they are in the boreal forest of North America. While it is not yet clear if the higher NDVI values result from greater biomass, greater crown closure or more rigorous growth of the understory, it is evident that this index is not a useful indicator of fractional forest cover. Thus the NDVI, by itself, should not be used as an additional input to the Chang et al. snow/microwave algorithm.

Global Snow Classification (G. Liston/USRA). A global implementation of Matthew Sturm's (Cold Regions Research and Engineering Laboratory, Fairbanks, Alaska) snow classification scheme is under development. The objective is to identify, based on common climatological variables and

vegetation type, where the different snow types will be found around the world. To do this we are using the highest resolution global data sets available. This includes a 0.5^{o} X 0.5^{o} gridded data set of observed precipitation and surface air temperature monthly mean climatologies (up to 60 years), and a 1^{o} X 1^{o} gridded vegetation type data set. Of the 33 vegetation categories, the data were restructured into 4 general surface classes: (1) water; (2) forest and woodland (i.e., tall); (3) shrubland, grassland, and tundra (i.e., short); and (4) ice. These precipitation, air temperature, and vegetation data sets were cast on common grids. The concept of a cooling degree month was introduced and used to generate a general index of integrated winter temperatures and precipitation. The resulting temperature, precipitation, and vegetation data have been used in conjunction with Sturm's snow classification scheme to generate global distributions of various snow types, including tundra, alpine, taiga, prairie, maritime, and ephemeral.

Modeling Local Advection of Momentum, Heat, and moisture during the melt of Patchy Snow Covers. A numerical atmospheric boundary layer model, based on higher-order turbulence closure assumptions has been developed and used to simulate the local advection of momentum, heat, and moisture during the melt of patchy snow covers. The coupled model includes solution of the mass continuity equation, the horizontal and vertical momentum equations, an E-epsilon turbulence model, an energy equation, and a water vapor conservation equation. Atmospheric buoyancy is accounted for, and a land-surface energy balance model is implemented at the lower boundary.

Model integrations indicate that snow melt processes occurring at micro and local scales produce significant variations in local surface fluxes. The melt energy is found to increase in a largely linear fashion as the fractional snow-covered area increases. The relationship between available melt energy and total snow covered area is nearly invariant with the size of snow patches comprising the snow cover. The simulations suggest that, for the purposes of computing areally averaged surface fluxes from grid-averaged atmospheric forcing, the subgrid-scale spatial variability of snow cover in regional and global land-atmosphere interaction models can be included through knowledge of the grid fraction covered by snow. This work will be presented by Glen Liston at the Tenth International Research Basins Symposium and Workshop, Spitsbergen, Norway, 28 August - 3 September 1994.

Future Plans

Plans are on-going for a joint snow/sea ice flight to be conducted in Alaska during the spring of 1995. The mission planning is being conducted with Don Cavalieri/Code 971. Flight hours have been secured from the NOAA P-3 in conjunction with their FOCI experiment. Arrangements are being made in an attempt to get passive microwave sensors installed on the P-3 at Wallops. Extensive hardware testing, etc. must be performed on the passive microwave sensors before they can be considered to be ready for the mission. Determination of the feasibility of preparing the sensors for a mission is currently being undertaken jointly between Code 974 (Dorothy Hall and Al Chang) and Code 971 (Don Cavalieri) and Code 972 (Dave Clem).

During the next few months, error analysis using DEM data will continue. Also, more work will be done to develop ICEMAP which is the algorithm to map sea ice. TM scenes of sea ice have been ordered and will be studied in greater depth.

Presentations and Papers

Presentations. Three MODIS/snow related presentations were given recently. Jim Foster/974 presented a paper entitled "Intercomparison of snow cover and snow mass in North America from General Circulation Models and remote sensing" at the American Meteorological Society meeting in Nashville, TN on January 26, 1994. Dorothy Hall presented a seminar at the Byrd Polar Research Center in Columbus, Ohio on February 23, 1994, part of which dealt with snow mapping and the future role of MODIS. Dorothy Hall gave a talk to GCIP and GEWEX office managers (at GSFC) on the development of the MODIS snow-mapping algorithm on March 30, 1994.

Abstracts/Papers

1) D. Hall/974 submitted an abstract to the Third Circumpolar Remote Sensing of Arctic Environments meeting and the abstract was accepted for presentation. A paper entitled "Determination of errors in snow mapping using Landsat TM and digital elevation model data in a mountainous area," by D.K. Hall, J.L. Foster, J.Y.L. Chien and G. Riggs, is in preparation and will be submitted to the Polar Record which will publish papers from the conference after peer review.

2) G. Riggs/RDC submitted an abstract to the IGARSS '94 convention to be held in Pasadena, CA in August of 1994. The abstract was accepted for presentation and the paper will be presented by V. Salomonson/900. The paper entitled "A snow index for the Landsat Thematic Mapper and Moderate Resolution Imaging Spectroradiometer," by G.A. Riggs, D.K. Hall and V.V. Salomonson, is in preparation.

3) G. Liston/USRA submitted an abstract to the Tenth International Northern Basins Research Symposium and Workshop, Spitsbergen, Norway, 28 August - 3 September 1994. The paper entitled "A microclimate model for northern applications," will be presented by G. Liston at the meeting. The paper will then be submitted for publication.

4) A paper entitled "Development of methods for automated mapping of global snow cover in the Earth Observing System era," to be authored by D.K. Hall, V.V. Salomonson and G.A. Riggs, is in preparation. This paper is being prepared in a format similar to the ATBD document that was turned in to EOS Project in March, and contains much of the information that is in the ATBD.